AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLXXI.

(Vol. XII.—December, 1883.)

GENERAL SUGGESTIONS AS TO THE CONDITIONS PROPER TO BE REQUIRED IN ORDINARY IRON HIGHWAY BRIDGE CONSTRUCTION.

By J. A. L. WADDELL, M. Am. Soc. C. E.

READ MAY 2D, 1883.

As the heading implies, the following suggestions are *general* in their nature: they are intended for *ordinary* iron highway bridges, and are designed to present to parties interested in bridge construction, more especially those upon whom falls the responsibility of letting bridge contracts, what in the writer's opinion are the requisites for a good structure. The parts relating to the proportioning of main members and details are in accordance with the writer's previous papers on "Bridge Piers, their Sizes and Bearings," "A System of Designing Highway

Bridges," and "Details in Ordinary Iron Bridges;" while the part relating to tests of materials is taken from Prof. H. T. Bovey's excellent little work on "Applied Mechanics." A few other portions are copied from approved specifications.

By ordinary highway bridges are meant simple truss bridges, having no novel or peculiar features, such as a combination of arches and trusses, cantilevers, &c.; in short, the bridges which one meets with every day in traveling through the United States.

These suggestions are general enough in their nature to include all the ordinary styles of truss, but are more particularly applicable to the Pratt and Linville, which are by far the most common trusses for iron highway bridges in America.

Highway bridges may be divided into three classes, viz.: those for cities and their suburbs which are subjected to the *continued* application of heavy loads; those for cities and their suburbs which are subjected to the *occasional* application of heavy loads; and those for country roads, where the traffic is lighter.

Calling these divisions Classes A, B and C, the following general suggestions are presented:

LIVE LOAD.

SPAN IN FEET.	MOVING LOAD PER SQUARE FOOT.	
	Classes A and B.	Class C.
0 to 50	100 pounds.	80 pounds.
50 to 150	90 "	80 "
150 to 200	80 "	70 "
200 to 300	70 "	60 "
300 to 400	60 "	50 "

Dead Load.—The dead load should include the weight of all the iron and wood in the structure, excepting those portions resting directly on the abutments, and whose weights do not affect the stresses in the trusses.

Also, if necessary, all allowance for snow, mud, paving or any unusual fixed load that may ever be placed upon the bridge.

Pine lumber is assumed to weigh two and a half ($2\frac{1}{2}$) lbs. per foot, b. m., and oak lumber four and a third ($4\frac{1}{3}$) lbs. per foot, b. m.

Should, in any bridge of less than two hundred (200) feet span, the calculated dead load differ more than seven (7) per cent., or in any bridge of more than two hundred (200) feet span more than four (4) per cent. from that assumed, the calculations of stresses, &c., should be made over with a new assumed dead load.

Wind Pressure.—The wind pressure per square foot for bridges in unusually exposed situations may be assumed as fifty (50) lbs. for spans of one hundred (100) feet and under, forty-five (45) lbs. for spans between one hundred (100) and one hundred and fifty (150) feet, and forty (40) lbs. for spans above one hundred and fifty (150) feet.

For bridges in positions not unusually exposed, these numbers may each be diminished by ten (10).

The total area opposed to the wind should be determined by adding together the areas of the floor, joists and lower lateral rods, and twice the areas of the truss, hand-rail, hub-plank, guard-rail and the rectangles circumscribed about the ends of the floor beams.

Limiting Length of Span for Different Clear Roadways.—The maximum lengths of span for the different clear roadways should be one hundred and forty (140) feet for twelve (12) feet roadways, one hundred and ninety (190) feet for fourteen (14) feet roadways, two hundred and sixty (260) feet for sixteen (16) feet roadways, and three hundred and fifty (350) feet for eighteen (18) feet roadways. By clear roadway is meant the distance between the inner edges of the batter brace plates.

Limit of Clear Headway.—The least allowable clear headway should be fourteen (14) feet, unless some local consideration cause this number to be increased. By clear headway is meant the vertical distance from the upper face of the flooring to the lowest part of the portal or overhead bracing.

Limiting Length of Span for Pony Trusses.—The greatest allowable length of span measured from centre to centre of end pins, or, in case of riveted connections at the shoes, between the intersections of the centre lines of lower chord and batter braces, should be sixty-five (65) feet for pony trusses or bridges without overhead bracing.

Limiting Depth of Pony Trusses.—The greatest allowable depth measured from centre to centre of chords for pony trusses without side bracing should be six (6) feet, and that for pony trusses with side bracing nine (9) feet.

Limiting Length of Span for Double Intersection Bridges.—The least allowable length of span measured from centre to centre of end pins, or, in case of riveted shoe connections, between the intersections of the centre lines of chord and batter braces for double intersection bridges, should be one hundred and fifty (150) feet.

Side Braces.—The least allowable batter for side braces in pony truss bridges should be five (5) inches to the foot, and all side braces should be made to resist both tension and compression. In no case should they have less strength than that of a $2\frac{1}{2}'' \times 2\frac{1}{2}'' - 5''$ angle iron.

Limiting Sizes of Sections.—No rods less than three-quarters ($\frac{3}{4}$) of an inch in diameter should be used in a bridge. No channels less than five (5) inches in depth should be used for upper chords, batter braces or posts, or less than four (4) inches in depth for lower chords or lateral struts. No bars less than one-half ($\frac{1}{2}$) inch thick should be used for diagonals, nor any iron less than one-quarter ($\frac{1}{4}$) inch thick anywhere in the bridge.

Expansion.—Any span above fifty (50) feet in length, resting on stone, concrete or iron foundations, should be provided with some means of allowing the bridge to expand and contract longitudinally with the variations of temperature, and, in spans of fifty (50) feet and under, care should be taken, especially when the bridge is erected in cold weather, to see that the stone-work of the abutments will not prevent a little sliding of the shoes.

Anchorage.—At least one end of every bridge should be anchored to the foundations. If the overturning moment of the greatest assumed wind pressure be more than half the resisting moment of the weight of the bridge, the latter should be anchored at the roller end also, but in such a manner as not to interfere with the expansion.

Sliding.—At the roller end of a bridge, if the frictional resistance to the sliding of the shoe in the direction of the rollers be not more than double the tendency to slide, produced by the wind pressure, a resistance equal to the difference of these two quantities with a factor of safety of two (2) should be provided.

Camber.—The camber of all bridges should be such that when they are

subjected to their heaviest loads the middle point of the centre line of the bottom chord may be at least one inch above the line joining the centres of end piers.

Vertical Sway Bracing.—In all deck bridges and in all through bridges, where the depth from centre to centre of chords is twenty-four (24) feet or over, vertical sway bracing should be used, to be proportioned so as to carry all the wind pressure concentrated at the upper and intermediate panel points (if there be intermediate struts) on the windward side, and at the upper panel point on the leeward side to the lower panel point on the leeward side.

Portal Bracing.—The portal bracing should be proportioned not only to resist the direct thrust caused by the wind pressure, but also the bending caused by the stresses in the knee bracing, according to the method given in Burr's work on "Stresses in Bridge and Roof Trusses."

Portal struts subjected to bending should first be proportioned for direct stress due to both wind pressure and the initial tensions on the rods meeting at the end of the strut, and then to their section should be added sufficient area to resist the bending.

Bending Effect on Posts and Batter Braces.—But the bending effect in the posts and batter braces caused by the stresses in the intermediate struts or knee braces need not be considered to occur when the bridge is fully loaded; so, unless the dead load stresses and the bending together call for more section than the dead and live loads combined, the bending in these members may be neglected.

Bending Effect on Lateral Struts.—Nor need there be any bending supposed to be caused by stresses in the knees connecting upper or intermediate lateral struts and posts, as the use of these knees may be considered simply to prevent vibration, and as, owing to the fact that these struts resist bending in the planes of their greatest dimensions, there is already a surplus of strength.

Stresses in Upper Lateral Struts.—The stresses in the upper lateral struts should be calculated for the wind pressure plus the sum of the transverse components of the initial tensions in the rods meeting at one end.

Initial Tension.—To allow for the stresses caused in adjustable members, the stress in each such member should be increased by the amount given in the following table :

$\frac{3}{4}$″ O	0.50 tons	$1\frac{1}{2}$″ O	2.00 tons
$\frac{7}{8}$″ O	0.75 "	$1\frac{5}{8}$″ O	2.25 "
1 ″ O	1.00 "	$1\frac{3}{4}$″ O	2.50 "
$1\frac{1}{8}$″ O	1.25 "	$1\frac{7}{8}$″ O	2.75 "
$1\frac{1}{4}$″ O	1.50 "	2 ″ O	3.00 "
$1\frac{3}{8}$″ O	1.75 "		

Square or flat bars are to receive the allowance for equivalent round rods.

Connection for Lateral Systems.—Whenever it be possible the lateral rods of both upper and lower systems should be connected directly to the chord pins. But if the rods exceed one and three-quarters ($1\frac{3}{4}$) inches diameter, bent eyes should not be employed. Lower lateral rods should not be attached to the floor beams unless the latter be riveted to the posts. To make the lateral rods clear the joists, wooden lateral struts resting on the floor beams, and having wrought-iron jaws at their ends attached to the chord pins, should be employed for the joists to rest upon. These wooden struts should be bolted every two or three feet through the top flange of the floor beam by half-inch bolts.

Should the sizes of the lateral rods be such as to prevent the use of bent eyes, pins dropped vertically through the jaws may be employed.

Stresses in End Lower Lateral Struts.—In figuring the stresses in a lower lateral strut at the roller end of a bridge, the stress caused by the wind pressure should be added to the transverse component of the initial tension in the end lateral rod, and from the same should be subtracted the product of the pressure on the windward shoe, when the bridge is empty and subjected to the greatest wind pressure, by the co-efficient of friction of iron upon iron, which is about 0.25 for this case.

Stiffened End Panels.—In any panel of a bridge where the longitudinal component of the greatest allowable working stress in the lower lateral rod exceeds the tension in the lower chord of that panel, caused by the dead load alone, the bottom chord of that panel should be made to resist both tension and compression. Where two channels are em-

ployed for the lower chord section, the effective area of the web alone should be counted upon to resist the tension.

Top Chord and Batter Brace Sections.—The top chords and batter braces should consist of two channels, with a plate above and latticing below, the lattice bars being riveted together where they cross. Broad lacing, with two rivets at each end, may be substituted for the latticing.

The top plate should be of the same section throughout, the increase of section from the ends to the middle being obtained by thickening the webs of the channels.

Post Sections.—Posts should consist of two channels, with lattice bars riveted together where they cross, or, as in the chords and batter braces, broad lacing may be substituted for the latticing. The upper ends of the posts may be either rigidly attached to the upper chords by plates, or may be hinged on the upper chord pins.

Upper Lateral Strut Sections.—Upper lateral struts should be formed of two channel bars, laced or latticed, and rigidly attached at their ends to the chords.

Sections of Bars.—Whenever practicable, the ratio of the width and depth of bars should be made as nearly as possible equal to one to four (1 : 4).

Working Tensile Stresses.—The intensities of working stresses for iron in tension in the various members should be as given in the following table :

Members.	Working Stresses in Tons of 2 000 Lbs. per Square Inch.	
	Class A.	Classes B and C.
Main diagonals and lower chord bars	5.00	6.25
Centre diagonals, counters and hip verticals	4,00	5.00
Flanges of rolled beams	5.00	6.00
Flanges of built beams (net section)	4.00	5.00
Lateral rods and vibration rods	7.50	7.50
Beam hangers	3.00	4.00

Working Compressive Stresses.—For struts composed of two channels with plate or lacing or latticing, the following formulæ may be used in finding the intensities of compressive stresses.

For chords, batter braces and posts in bridges of Class A,

$$p = \frac{\dfrac{f}{1 + \dfrac{H^2}{C}}}{4 + \dfrac{H}{20}}$$

and for lateral struts in Class A, and all compression members in Classes B and C,

$$p = \frac{\dfrac{f}{1 + \dfrac{H^2}{C}}}{4 + \dfrac{H}{30}}$$

p being the intensity of working stress ;

$$H = \frac{\text{length of strut}}{\text{diameter of strut;}}$$

$$f = \begin{cases} 38\,500 \text{ for two fixed ends,} \\ 38\,500 \text{ for one fixed end and one hinged end,} \\ 37\,800 \text{ for two hinged ends,} \end{cases}$$

$$\text{and } C = \begin{cases} 5\,820 \text{ for two fixed ends,} \\ 3\,000 \text{ for one fixed end and one hinged end,} \\ 1\,900 \text{ for two hinged ends.} \end{cases}$$

Where I beams are employed for intermediate lateral struts or end lower lateral struts, the intensities of working stresses may be found by dividing the ultimate resistances, as given by the maker, by the product of the area of the section and the expression $\left(4 + \frac{H}{30}\right)$, H being the number of diameters.

For the flanges of rolled beams the intensities of working compressive stress may be taken equal to five (5) tons for bridges of Class A, and six (6) tons for bridges of Classes B and C. For the flanges of built beams the intensities of working compressive stress may be taken equal to four (4) tons on the gross section for Class A, and five (5) tons on the gross section for Classes B and C.

Working, Shearing and Bending Stresses.—The intensities of working shearing stresses on pins and rivets should be three (3) tons for bridges

of Class A, and three and three-quarter ($3\frac{3}{4}$) tons for bridges of Classes B and C. The intensities of working bending stresses on pins should be seven and a-half ($7\frac{1}{2}$) tons for bridges of Class A, and nine and three-eighths ($9\frac{3}{8}$) tons for bridges of Classes B and C. For pins belonging wholly to the lateral systems in bridges of either class, the intensity of working bending stress may be taken equal to eleven and a quarter ($11\frac{1}{4}$) tons.

Where steel pins are employed the intensity of working bending stress should not be taken greater than twelve (12) tons for bridges of Class A, or fifteen (15) tons for bridges of Classes B and C, unless special experiment on the steel used shows a greater ultimate resistance than sixty (60) tons per square inch, in which case a factor of five (5) may be used for Class A, and a factor of four (4) for Classes B and C.

Sizes of Upper Lateral Rods.—In many cases, the stresses in the upper lateral systems in through bridges, or the lower lateral systems in deck bridges, call for sections of rods which would be practically too small; the limits for the diameters of the end rods in such cases may be taken from the following table:

Diameter of End Rod.	Length of Span.	
	From	To
$\frac{3}{4}''$	....	60′
$\frac{7}{8}''$	60′	80′
1″	80′	100′
$1\frac{1}{8}''$	100′	140′
$1\frac{1}{4}''$	140′	170′
$1\frac{3}{8}''$	170′	200′

Stiffened Hip Verticals in Pony Trusses—Trussing.—Hip verticals in pony trusses should be stiffened so as to resist compression. In these members and in the posts of small pony truss bridges, where there is an excess of strength, trussing may be used, but in no other case.

Upset Rods.—Middle panel diagonals, counters, lateral rods, vibration

rods, and all other adjustable rods should have their ends enlarged for the screw threads, according to the table given on pages 126 and 127 of Carnegie's Pocket Companion.

Minimum Dimensions of Chord and Batter Brace Plates.—The minimum dimensions for the top plate in a top chord or batter brace may be taken from the following table. Should the width employed exceed that given in the table by from forty (40) to sixty (60) per cent., the thickness should be increased by one-sixteenth ($\frac{1}{16}$) of an inch; if it exceed from sixty (60) to eighty (80) per cent., the thickness should be increased by one-eighth ($\frac{1}{8}$) of an inch:

DEPTH OF CHANNEL.	MINIMUM THICKNESS.	MINIMUM WIDTH.
5″	$\frac{1}{4}$″	7″
6″	$\frac{1}{4}$″	8″
7	$\frac{1}{4}$″	9″
8″	$\frac{1}{4}$″	10″
9″	$\frac{5}{16}$″	$11\frac{1}{2}$″
10″	$\frac{5}{16}$″	$12\frac{1}{2}$″
12″	$\frac{3}{8}$″	15″

Sizes of Stay Plates.—The dimensions of stay plates in struts, where latticing or double-riveted lacing is employed, should not be less than those given in the following table. If the distances between the inner faces of the channels be more than the depth of the latter and less than one and a quarter ($1\frac{1}{4}$) times the same, either the thickness of the stay plates should be increased one-sixteenth ($\frac{1}{16}$) of an inch above that given in the table, or the width should be increased sufficiently to allow space for one more rivet at each side; or, if the distance between the faces be between one and a quarter ($1\frac{1}{4}$) and one and a half ($1\frac{1}{2}$) times the depth of the channels, both of these changes in the thickness and width should be made; while, if the distance between the faces be more than one and a half ($1\frac{1}{2}$) times the depth of the channels, either the thickness should be increased by one-sixteenth ($\frac{1}{16}$) of an inch and the width sufficiently for two more rivets on a side, or the thickness should be increased

one-eighth ($\frac{1}{8}$) of an inch, and the width sufficiently for one more rivet on a side:

Depth of Channel.	Thickness of Stay Plates.	Width of Stay Plates.
4"	$\frac{1}{4}$"	4"
5"	$\frac{1}{4}$"	4"
6"	$\frac{1}{4}$"	4"
7"	$\frac{1}{4}$"	4"
8"	$\frac{5}{16}$"	4"
9"	$\frac{5}{16}$"	$6\frac{1}{2}$"
10"	$\frac{5}{16}$"	$6\frac{1}{2}$"
12"	$\frac{3}{8}$"	$6\frac{1}{2}$"

But if single-riveted lacing be used, the dimensions of the stay plates may be taken from the next table, the same allowance as before being made for the increased distances between channels:

Depth of Channel.	Thickness of Stay Plates.	Width of Stay Plates.
4"	$\frac{1}{4}$"	4"
5"	$\frac{1}{4}$"	4"
6"	$\frac{1}{4}$"	$6\frac{1}{2}$"
7"	$\frac{1}{4}$"	$6\frac{1}{2}$"
8"	$\frac{5}{16}$"	$6\frac{1}{2}$"
9"	$\frac{5}{16}$"	$6\frac{1}{2}$"
10"	$\frac{3}{8}$"	$8\frac{1}{2}$"
12"	$\frac{3}{8}$"	$8\frac{1}{2}$"

Diameters of Rivets for different Channels.—For attaching plates and lattice bars to channels, the least diameters of the rivets to be used may

be taken from the following table, and the greatest diameters should not exceed those given in the table, in any case, by more than one-eighth ($\frac{1}{8}$) of an inch:

Depth of channel................	4″	5″	6″	7″	8″	9″	10″	12″
Diameter of rivets................	$\frac{1}{2}$″	$\frac{1}{2}$″	$\frac{5}{8}$″	$\frac{5}{8}$″	$\frac{5}{8}$″	$\frac{3}{4}$″	$\frac{3}{4}$″	$\frac{3}{4}$″

Inclinations of Lattice and Lacing Bars.—Lattice bars should make with each other, as nearly as circumstances will permit, angles of ninety (90) degrees, and lacing bars angles of sixty (60) degrees.

Sizes of Lattice Bars.—The minimum sizes of lattice bars for the different depths of channels, when the distance between the inner faces of the latter does not exceed their depth, may be taken from the following table; but if this distance exceed the depth and be less than one and a quarter ($1\frac{1}{4}$) times the same, either the thickness of the bars should be increased by one-sixteenth ($\frac{1}{16}$) of an inch, or their width by one-half ($\frac{1}{2}$) of an inch; if the distance between faces be greater than one and a quarter ($1\frac{1}{4}$) times the same, both of these changes in thickness and width should be made; while, if the distance between faces exceed one and a half ($1\frac{1}{2}$) times the depth, the thickness should be increased by one-eighth ($\frac{1}{8}$) of an inch, and the width by one-half ($\frac{1}{2}$) of an inch.

This table can be made to apply to single rivet lacing by increasing the widths of the bars by three-eighths ($\frac{3}{8}$) of an inch, and making the same allowance for increased distance between faces of channels:

Depth of Channel.	Thickness of Lattice Bars.	Width of Lattice Bars.
4″	$\frac{1}{4}$″	$1\frac{1}{4}$″
5″	$\frac{1}{4}$″	$1\frac{3}{8}$″
6″	$\frac{1}{4}$″	$1\frac{1}{2}$″
7″	$\frac{1}{4}$″	$1\frac{5}{8}$″
8″	$\frac{5}{16}$″	$1\frac{3}{4}$″
9″	$\frac{5}{16}$″	$1\frac{7}{8}$″
10″	$\frac{5}{16}$″	2″
12″	$\frac{3}{8}$″	$2\frac{1}{8}$″

Splice Plates.—The length of a splice plate may be determined by the number of rivets necessary to transfer the stress from one main member to the other; the sum of the working resistances to shearing of all the rivets on either side of the joint should not be less than the stress in the main member upon that side, nor should the latter stress be greater than the sum of the working resistance at the bearing surfaces of the rivets on that side of the joint.

When practicable, a splice plate should be placed on each side of every member where a splice occurs.

The transmission of compressive stresses should be considered as entirely through the medium of the rivets and connection plates, and these should be proportioned accordingly.

Reinforcing Plates.—Simple reinforcing plates, or plates riveted to webs at pin-holes in order to compensate for strength lost there, or to provide additional bearings for the pins, should have as many rivets to attach them to the webs as will give shearing and bearing resistances for same at least equal to the greatest allowable stresses upon the reinforcing plates.

Cover Plates.—Cover plates for top chords or batter braces should have the same section as the chord or batter brace plate, the joints of which they cover, and enough rivets on each side of the joint to take up the greatest allowable stress that could ever come upon the cover plate.

Extension or Connecting Plates.—All extension or connecting plates on the ends of struts, for the purpose of attachment by pins or rivets, should be designed of such a strength that they will bear without buckling the ultimate resistance to compression of the struts, and to provide sufficient bearing for pins and rivets. There should be a sufficient number of the latter to transfer all the stress in the post to the extension or connecting plates.

Shoe Plates and Roller Plates.—No shoe plates or roller plates should have a less thickness than three-quarters ($\frac{3}{4}$) of an inch.

Beam Hanger Plates.—Beam hanger plates should never be made less than three-quarters ($\frac{3}{4}$) of an inch thick, and their areas should be such that the hanger nuts will always have a full bearing thereon. The necessary thickness for a beam hanger plate may be found by considering it as a beam uniformly loaded by the whole weight that comes on the hangers, the length of said beam being the distance between the centre

of the holes through which pass the ends of one hanger, and its width being the extreme dimension of the plate measured parallel to the floor beam. The working stress for bending in the plate should be taken equal to that used in proportioning the floor beam.

Riveting.—In riveted work all joints should be squarely and truly dressed, and the rivet holes accurately spaced.

No rivets with crooked heads or heads not formed accurately on the shank, or rivets which are loose either in the rivet holes or under the shoulders, should be allowed in a bridge.

Rivet holes in chords may be spaced as nearly as practicable three (3) inches centre to centre near the panel joints, and four inches centre to centre elsewhere.

No rivet holes should be less than one and a half ($1\frac{1}{2}$) diameters from the edge of a plate, and the diameter of a hole should never exceed that of the rivet by more than one-sixteenth ($\frac{1}{16}$) of an inch.

When two or more thicknesses of plate are riveted together in compression members, the outer row of rivets should not be more than three (3) diameters from the side edge of the plate.

All the rivet holes of the respective parts of any structure should be made to exactly coincide, either by drilling the holes full size through the connecting portions after being put together, or by sub-punching the pieces separately and afterwards reaming the combined rivet holes to proper size. In all cases the burrs should be removed by slightly countersinking the edges of the holes.

All rivets in splice or tension joints should be systematically arranged, so that each half of a tension member or splice plate will have the same uncut area on each side of its centre line. No rivet should have a less diameter than the thickness of the thickest plate through which it passes, nor, in any case, less than half ($\frac{1}{2}$) an inch.

Use of Bolts.—The use of bolts instead of rivets should be avoided whenever possible.

Floor Beam Stiffeners.—Floor beams should be well stiffened at the points of support, and at several intermediate points, the distance apart of the stiffeners being made no greater than twice the depth of the beam when the ratio of thickness of web to depth of beam is not less than one-eightieth ($\frac{1}{80}$), and no greater than one and a half ($1\frac{1}{2}$) times the depth when this ratio is one over one hundred and twenty ($\frac{1}{120}$); distances for intermediate ratios being interpolated.

Angle irons rather than the irons should be used as stiffeners, and be placed opposite to each other instead of being staggered.

They should extend from the upper leg of the upper flange to the lower leg of the lower flange of the floor beam, being made flush with the other legs of the flanges by means of filling plates.

Rivets in Flanges of Beams.—In spacing the rivets in the flanges of floor beams, the latter should be divided into equal portions of about two feet in length; the stresses in the flanges may be found at the points of division, and there should be enough rivets between any consecutive points of division to take up the difference of the stresses at the points, providing that the rivets are not spaced more closely than two and a half ($2\frac{1}{2}$) diameters, nor more than six inches apart.

Limiting Depths of Floor Beams.—The greatest allowable depths for floor beams with webs of different thickness may be taken from the following table :

Thickness of web........................	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$
Depth of beam..........................	30″	38″	45″

Eyes.—In welded heads the length of metal behind the pin should be at least equal to the diameter of the pin; while, in hammered heads, the amount should be the same as that above or below the pin.

The least amount of metal in the heads across the pins is given in the following table :

Width of Bar.	Diameter of Pin.	Metal in Head across Pin.	
		Welded.	Hammered.
1.	0.80	1.40	1.50.
1.	1.04	1.50	1.50
1.	1.12	1.50	1.53
1.	1.20	1.50	1.56
1.	1.28	1.50	1.60
1.	1.36	1.55	1.72
1.	1.43	1.60	1.76
1.	1.50	1.67	1.85
1.	1.64	1.67	1.95
1.	1.77	1.70	2.05
1.	1.90	1.76	2.21

In loop eyes the distance of the inner point of the loop from the centre of the pin should be not less than three times the diameter of the pin, where the section at the eyes is reduced to a minimum; but if the bar be simply turned around the pin and welded, this distance may be decreased. Pin-holes in eye-bars should be bored to an exact size and distance, and to a true perpendicular to the line of stress. No error in the length of bar or diameter of pin-hole exceeding one sixty-fourth ($\frac{1}{64}$) of an inch should be allowed, nor any variation of more than one-sixteenth ($\frac{1}{16}$) of an inch between the centre of the eye and the centre line of the bar.

Pins.—Pins should be proportioned to resist the bending produced in them by the bars or struts which they connect.

No pin should have a diameter less than eight-tenths ($\frac{8}{10}$) of the depth of the deepest bar coupled thereon, nor should it vary from that of the eyes of the bars coupled thereto by more than one-fiftieth ($\frac{1}{50}$) of an inch.

Pin Bearing.—Where a pin bears against a reinforced channel bar, the web of the latter should not be assumed to take up any bearing

stress, unless the reinforcing plate or plates were riveted to it before the pin-hole was bored.

Expansion Rollers.—Expansion rollers should be proportioned by the formula, $P = \sqrt{0.135d}$, where P is the working load in tons per lineal inch of roller, and d is the diameter of roller in inches. The least allowable diameter for roller should be one and three-quarters ($1\frac{3}{4}$) inches for bridges of Class A, and one and a-half ($1\frac{1}{2}$) inches for bridges of Classes B and C.

The spaces between rollers should never exceed three-quarters ($\frac{3}{4}$) of their diameter.

Turnbuckles and Sleeve-Nuts.—All turnbuckles and sleeve-nuts should be made so strong that they will be able to withstand without rupture the ultimate pull of the rods which they connect. U-nuts are not to be used in any part of a bridge.

Sizes of Nuts.—The dimensions of all square and hexagonal nuts for the various diameters of rods may be taken from "Carnegie's Pocket Companion," pages 130 and 131, excepting those nuts on the ends of pins, which are subject to but a slight tendency to shear the th[illegible] In this case these dimensions may be diminished in direct propor[illegible]on to this tendency until the thickness reaches the limit of one-half ($\frac{1}{2}$) of an inch.

Washers and Nuts.—Washers and nuts should have a uniform bearing.

Jaws.—Great care should be taken in designing jaws for the end of any strut that they be so strong in every respect that when the strut is subjected to its ultimate load it will fail in the middle rather than at the ends.

Brackets.—Brackets or knees should be used to connect each overhead strut to the posts or batter braces. They may be of tee, angle or channel iron, and made straight instead of curved.

Cutting off the Flanges of Channels.—The flanges at the ends of channel bars should never be cut away, if it be possible to avoid doing so; if not, there should be sufficient reinforcing used to make the strut as strong as it would have been with the flanges uncut.

Iron Hand-Railing.—If the hand-rail employed be of iron, it should be made strong and rigid, and be firmly attached to the floor beams.

Sizes of Flooring and Joists.—Pine flooring should be made at least three (3) inches thick, and oak flooring at least two and a-half ($2\frac{1}{2}$) inches

thick. It should be laid with close joints, and well spiked to each joist with seven (7) inch cut spikes. Joists should be proportioned by the formula, $W = \frac{b\,d^3}{c\,l^2}$, where W is the safe, uniformly distributed load in tons, b the breadth of the joist in inches, d the depth of same in inches, l the length in feet, and $c = 16$ for pine and 12.5 for oak. Where the load is concentrated on wheels, it may be considered as supported equally between the joists directly under the wheels and those contiguous to the same; *i. e.*, the wheels on one side of a wagon are supposed to be placed directly over a joist, which joist is assumed to take half their load, the remaining half being equally divided between the two adjoining joists. All concentrated loads should be properly reduced to equivalent uniformly distributed loads, in respect to deflection, before applying the formula. The minimum live load to be used for proportioning joists for bridges of Classes A and B may be taken as one hundred (100) pounds per square foot; and for bridges of Class C eighty (80) pounds per square foot, regardless of the length of span of the bridge.

Wooden Hand-Rails, &c.—Wooden hand-railing may be made of pine, the posts being 4″ × 6″ × 4′, with two runs of 2″ × 6″ timbers, one on its flat and the other below on edge to support the first, for a hand-rail; and one run of 2″ × 12″ hub plank. The latter and the lower run of 2″ × 6″ may be let into the posts to their full depth, and spiked to same with five (5) inch cut spikes, and the posts are to be halved on to the outer joists, to which each one is to be bolted by two (2) five-eighth (⅝) inch bolts.

Guard-rails may be of 6″ × 6″ pine, bolted to the floor once in, at most, every five (5) feet by five-eighth (⅝) inch bolts.

Details not Previously Mentioned.—Finally, as regards the proportioning of any structure, if cases should occur which are not covered by the preceding specifications, the following rule should, in all such cases, be adhered to: "Details should always be proportioned so as to resist every direct and indirect stress that may ever come upon them under any probable circumstances, without subjecting any portion of their material to a stress greater than the legitimate corresponding working stress."

Cast-Iron.—No cast-iron should be used anywhere, unless it be for washers for hand-rail post bolts.

Field Riveting.—Field riveting should be done with the button set; the heads of the rivets should be hemispherical, and no rough edges be left.

Painting.—All iron-work should be thoroughly cleaned (by acid or otherwise), and all scale or oxide formed in rolling or working removed from the surface before painting. All iron-work should have one coat of metallic paint before leaving the shop, and before corrosion commences. All turned and faced parts should receive a coat of tallow, mixed with white-lead, before shipment.

After erection, all iron-work should receive two coats of metallic paint, mixed in equal parts of paraffine and linseed oil, dissolved and applied while hot.

Timber.—All timber should be of the best quality, free from wind shakes, large knots, decayed wood, sap, or any defect that would impair its strength or durability.

Quality of Workmanship.—All workmanship should be first-class; abutting joints truly planed or dressed, so as to secure a perfect bearing; the pin-holes in chords and posts bored as truly as specified for the eye-bars; and no rough corners or edges left on the iron-work.

Tests of Materials.—All wrought-iron should have an elastic limit of not less than twenty-six thousand (26 000) pounds per square inch.

Full-sized bars of flat, round or square iron, not over four and a half (4½) square inches in sectional area, should have an ultimate strength of fifty thousand (50 000) pounds per square inch, and should stretch twelve and a half (12½) per cent. of the whole length.

Bars of a larger sectional area than four and a half (4½) square inches may be allowed a reduction of one thousand (1 000) pounds per square inch for each additional square inch of section, down to a minimum of forty-six thousand (46 000) pounds per square inch.

Specimens of a uniform section of at least one square inch taken from bars of four and a half (4½) square inches section and under, should have an ultimate tensile strength of fifty-two thousand (52 000) pounds per square inch, and stretch eighteen (18) per cent. in eight (8) inches.

Similar specimens from bars of a larger section than four and a half (4½) square inches may be allowed a reduction of five hundred (500) pounds per square inch for each additional square inch of section down to a minimum of fifty thousand (50 000) pounds per square inch.

Similar sections from angle and other shaped iron should have an

ultimate strength of fifty thousand (50 000) pounds per square inch, and stretch fifteen (15) per cent. in eight (8) inches.

Similar specimens from plate iron should have an ultimate strength of forty-eight thousand (48 000) pounds per square inch, and stretch fifteen (15) per cent. in eight (8) inches.

All iron for tension members should bend cold, without cracking, through an angle of ninety (90) degrees to a curve of which the diameter is not more than *twice* the thickness of the piece, and at least one sample in three should bend one hundred and eighty (180) degrees to this curve without cracking.

Specimens from plate, angle and other shaped iron should bend cold, without cracking, through an angle of ninety (90) degrees to a curve, of which the diameter is not more than *three* times the thickness of the specimen.

Rivets should be of the best quality of iron, and so ductile that a bar of the diameter of the largest rivet will bend close through one hundred and eighty (180) degrees without sign of fracture.

Tests of Structure.—On the completion of the entire structure, any bridge, after being in constant use for one day, may be tested by a load equal to that for which it was designed remaining upon it for at least one hour without showing any permanent set.